FLORA OF THE WHITE LAKE REGION, MICHIGAN, AND ITS ECOLOGICAL RELATIONS.

(WITH MAP)

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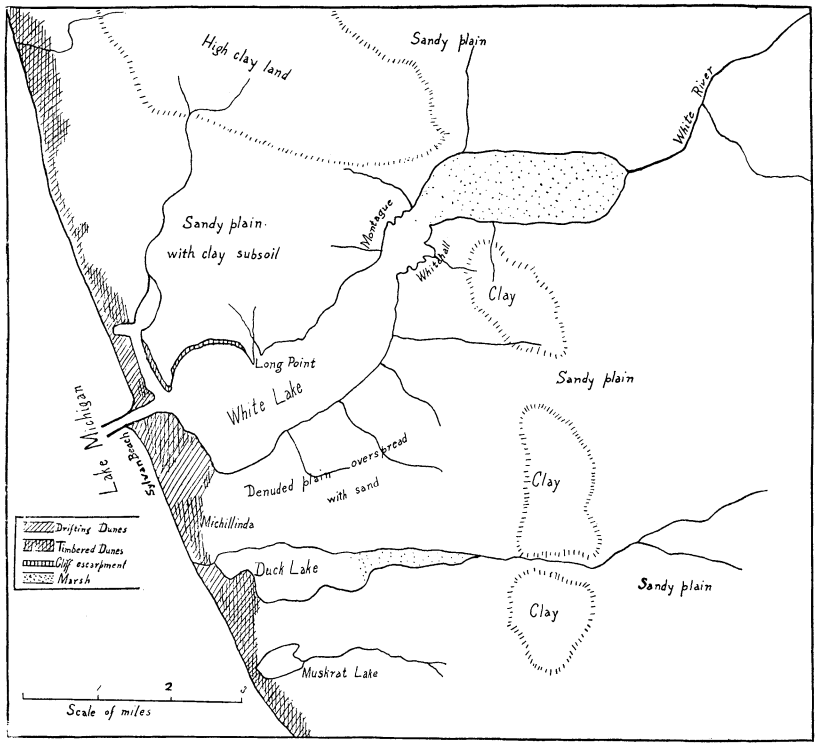
WHILE passing the latter part of August 1899 at White lake, Michigan, an opportunity was given to study the flora of the vicinity. It proved interesting in its geographical and ecological relations, and was instructive as a representative example of similar areas by the eastern shore of Lake Michigan, with which I had had more or less acquaintance in past years. White lake is one of those bodies of water, or river-lakes as they have been termed, common in western Michigan, where a stream expands into a small lake before its entrance into Lake Michigan. The river properly ends at the head of the lake where it is bordered by a tract of marshy ground abounding in reeds, wild rice, and various aquatic plants growing in the sediment deposited at its mouth and along its banks, and forming a filling which continually encroaches on the ground once occupied by the lake waters. The lake narrows again into a short outlet of river dimensions when it enters Lake Michigan. If the water of the streams forming them is of sufficient volume these lakes furnish excellent harbors, and become sites of cities and villages, while their shores are often occupied by summer cottages. They are primarily due to the geological structure of the region, dating back to the changes of level which the great lakes were subject to in Pleistocene times. Areas have been worn out by wave action, degraded by meteoric and river waters, or submerged by subsidence, which subsequently have been partly filled by sand driven in by westerly winds aided by deposits at the river's mouth. Such areas do not occur on the western shore of Lake Michigan in Wisconsin and Illinois. The eolian factor is the principal one in the filling process, and the region

is consequently in its surface characters mainly a dune formation. A basin or bay-like area formed in the drift clay of the glacial period is filled with sand above the water level, the lake still occupying a portion of this area. The sand forms a dam



MAP OF THE WHITE LAKE REGION.

This map is based on one published in *The American Geologist* (1 : 143. 1888), in an article "The river-lake system of western Michigan," by C. W. Wooldridge, M.D. Only a few minor changes have been made in the portion of the map used, to indicate better some points covered by the present article.

along the shore of Lake Michigan and across the outlet of the river which impounds the water above. Doubtless the small lake owes its immunity to filling to these dunes becoming timbered before the area could be entirely filled, leaving only a river channel. Vegetation crept in from the surrounding

timbered region which lay above the level of the waters and contested the ground with the wind-driven sand until the dunes by the lake shore, becoming covered and fixed, formed a barrier against further encroachment. The surface sand washed up by the waves of the lake is now piled up on the shore dunes which tend to become higher as long as the tree covering remains as a protection. The study of the flora of such a region is important since it shows the kinds of vegetation which have this ability.

White lake is about five miles long by one to two miles wide, its deepest part being eighty or more feet. It is an expansion of White river. At the entrance of the river into the lake are two villages, Whitehall on the south side and Montague on the north. At the present outlet into Lake Michigan is Sylvan beach, a collection of summer residences, and another, Michillinda, lies just south on the Michigan shore. South of Michillinda are two similar but much smaller lakes, Duck lake and Muskrat lake. The latter is little more than a pond without a visible outlet at present, whose surplus waters must make their way into Lake Michigan by seeping through the sand. The surroundings and flora of these were likewise examined. Lying in the midst of a dune formation their shores are everywhere sandy. The region as a whole is a sandy plain with low ridges of sand more or less parallel, having a north and south trend. Moving or active dunes occur at the southwest side of White lake and by the shore of Lake Michigan. One of these lies between the old outlet of White lake and the lake shore. The natural outlet has been superseded by a short cut into Lake Michigan at Sylvan beach. The original outlet had been crowded northward by drifting sand, and ran parallel with the shore of the large lake for nearly a mile before the water escaped. This is now silted up by sand and the old outlet is a lagoon opening into White lake at its inner end.

Though this dune formation rests on a base of clay the underlying clay rarely appears in sight either by the shores of the small lakes or the contiguous shore of Lake Michigan. Sylvan beach is on a sand covered hill of drift clay, and there are low

escarpments which indicate the presence of the clay elsewhere, as along a portion of the north shore of White lake. One must go five or six miles from the lake to find the clay at the surface except near Montague and Whitehall where it appears *in situ*. The sand of the more level portion varies in depth from two or three feet to twenty-five or thirty or more, rising in low bluffs by the shores of the lake. The line of contact of the clay and sand is best shown by a series of springs along the shore and by the brooks.

This regional structure has its effect on the drainage, and by molding the hydrographic character of the basin has a corresponding influence on the flora. This differs very materially in species and distribution on the opposite sides of White lake. On the south side springs and streams are common, and the clay comes nearer to the surface, especially in depressions between the low sand ridges where the streams mainly occur. On the north side springs and streams are absent except some small ones at Montague. A large brook comes from the clay hills at the north through a rather deep valley lying between the high shore dunes and the main body of the plain, and makes its way into the old outlet of White lake that lay in the same depression. It is a perennial stream of cool water abundantly fed by springs and has the same effect on the flora along its course as does the stream-fed area to the south of the lake. Between this stream and Montague there are no beds even for storm water except near Long point where a couple enter the head of a narrow bay, now a pond and marsh, cut off from the lake by a filling of sand and saw-mill refuse. As they were dry at the time I was there, they were plainly only channels for storm water. The rain as it falls sinks into the sand and makes its way to the lake at or below the water level, or eastward toward Montague and to the perennial brook to the westward.

This indicated a drier region and a greater depth of sand. The flora was correspondingly modified. It was prevailingly xerophytic, ericaceous and arenophilous plants predominating.

On the south side it was much more varied, heath-loving plants mingling more with mesophytic kinds. In the sand plain to the north the tree covering was almost wholly white pine and oak, *Quercus velutina*, *Q. coccinea*, *Q. rubra*, *Q. alba*, and *Q. macrocarpa* being observed, while on the south side, as well as by Duck lake, Muskrat lake, and the valley to the west of the plain, these trees were interspersed with beech, sugar maple, basswood, hemlock, white elm, black ash, white ash, black birch, paper birch, silver maple, tupelo, black cherry, wild red cherry, sassafras, and white cedar. The difference was manifest in the color of the corn in the fields and the behavior of the grass. On the north side the corn was pale and the grass with difficulty made a sod; on the south side the corn had a deeper green, but not the rich green color which comes from a deep firm soil, and the grass sodded fairly well in damper places. But wherever there was a bare surface, as in plowed fields and roadways, the ground showed a sand plain.

The floral societies formed by this mixture did not readily harmonize with ideas of plant ecology based on experience with plants growing in a soil more natural to them and under conditions more uniform. I was familiar with this in the dune region at the head of Lake Michigan, where the herbaceous vegetation is much varied and the arboreous considerably so, but the tree covering south of White lake much exceeded it in variety. It was a surprise to find on the top of a dune, or sand covered hill with a base of clay like that on which Sylvan beach is located, a comparatively pure beech wood. The hill is capped with sand blown up from the neighboring beach. Its south end to some extent still battles with the winds, and owes its immunity in part to their prevailing direction from the northwest, which makes their work more effectual on the north end of the dunes lying toward Michillinda. These dunes, together with the sand washed up in the low interval between, furnish the material of the large active dune now encroaching on White lake. The timbered dune between this opening and Michillinda is high and steep on both sides. Within the space

of a few square rods on the top bordering the part against which the wind was acting I made a list of the following species: beech, sugar maple, red oak, black cherry, hemlock, white pine, white cedar, common juniper, witch hazel, poison ivy, two dogwoods (*C. stolonifera* and *C. Baileyi*), and the willow, *Salix glaucophylla*. On the ground the lesser growth was composed of *Pyrola secunda*, *Arctostaphylos Uva-ursi*, *Polygala paucifolia*, *Aralia nudicaulis*, *Campanula rotundifolia*, *Mianthemum Canadense*, and *Solidago caesia*. The list of herbaceous plants could have been easily increased by walking about a little, but I purposely sat down so as to make a list in sight from a single point of view as a limitation. This was on a narrow crest of sand with a steep timbered slope to the south, and a still steeper one of bare sand to the north extending down to the low area of moving sand a hundred or more feet below. It was possible for all this variety of vegetation to be in time blown away, though the work of the wind was slow, for there was evidence at hand of what it had already done. It was also plain that the plants grew in a soil of sand so little compacted as to be easily moved by the wind when once the covering had been removed.

In the sand plain north of the lake the herbaceous and shrubby flora was less diversified but still well represented in species. Where the oaks prevailed the tree covering was quite open. There were dense groves of young white pine, for the old trees had nearly all been removed to the sawmill. From the stumps which remained it was seen to have been a mixed forest of pine and oak at the time the trees were cut. The undergrowth varied according to the density of the tree covering and somewhat according to its kind, whether of oak or pine. The common wintergreen, the pyrolas, and pipsissiwa were more generally found under the dense growth of pine. The usual ericaceous plants were *Epigæa repens*, *Arctostaphylos Uva-ursi*, *Gaultheria procumbens*, *Pyrola secunda*, *P. chlorantha*, *P. elliptica*, *P. rotundifolia*, *Gaylussacia resinosa*, *Vaccinium Pennsylvanicum*, and *V. vacillans*. In somewhat more fertile areas or deeper humus soil *Monotropa uniflora* was frequent and *M. Hypopitys* was detected

once. The fringed polygala was also frequent, generally in company with the trailing arbutus, which was very abundant, and together they must have made a fine floral display in early May. The polygala occurred under quite different conditions south of the lake, for besides on dunes and the drier sand plain it found a home in the damp sand as a companion of such plants as *Clintonia borealis* and *Trientalis Americana*. *Vaccinium Canadense* also accompanied the other huckleberries in moister areas south of the lake. In the dry plains both north and south were great quantities of *Comptonia asplenifolia*, sometimes quite exclusive of smaller growth. *Pteris aquilina* was equally abundant in spots but not covering such wide spaces as the *Comptonia*. It was the only fern observed in the dry sand plain. *Rhus copallina* was the most common sumach, often much dwarfed and flowering when a foot or less in height. *R. aromatica* and *Shepherdia Canadensis* were frequent along the bluff shores of the lake and occasionally were seen elsewhere in the woods. The most frequent papilionaceous plants of the season were *Lespedeza polystachya* and *L. Stuvei* var. *intermedia*, *Desmodium paniculatum* and *D. nudiflorum*, the latter often under the pines with the pyrolas. The sunflower was chiefly represented by *Helianthus divaricatus*, slender, often dwarfed, and bearing small heads barely an inch in diameter. *Liatris scariosa* was the common blazing-star. The principal goldenrods were *Solidago hispida*, *S. juncea*, and *S. nemoralis ;* and the asters mostly *Aster corymbosus*, *A. azureus*, and small forms of *A. laevis*. The round-leaved orchid, *Habenaria Hookeriana*, occasionally occurred, and more commonly *Lycopodium complanatum*.

These were the most typical plants seen in the wooded sand plain north of White lake, a list by no means exhaustive even for the time of the year, but representative of the flora. Nearly all of them were met with on the south side, commonly on the dry sand ridges, and helped to give the flora south of the lake a more mixed and diversified character.

The cool brooks fed by springs, the springy and swampy places south of the lake, had a tree growth in which the white

cedar, black ash, hemlock, cherry birch, paper birch, and white pine were variously intermixed. *Alnus incana*, *Cephalanthus occidentalis*, *Ilex verticillata*, *Pyrus arbutifolia*, *Rosa Carolina*, *Salix discolor*, and *S. cordifolia* were the more common shrubs. The damp shaded reaches along the streams showed such plants as *Mitella nuda*, *Mitchella repens*, *Cornus Canadensis*, *Clintonia borealis*, *Trientalis Americana*, and *Habenaria psycodes*. Here the ferns obtained the proper conditions of growth and occurred in considerable variety. The most frequent were *Aspidium Thelypteris*, *A. spinulosum*, *Osmunda cinnamomea*, *O. regalis*, *Asplenium Filix-foemina*, *A. acrostichoides*, *Onoclea sensibilis*, *Phegopteris Dryopteris*, and *Adiantum pedatum*. Some of these, especially the last two, occurred in the drier area of beech woods along with the Pteris, though this was more abundant in the oak woods. The most interesting fern of the swampy ground was a *Botrychium ternatum*. It was abundant in a locality where the tupelo grew, and where the ground was also closely shaded by a larger fern, *Osmunda regalis*. The botrychiums were from three to twelve inches high, some so hidden that the fronds of the osmunda had to be pulled aside to find them. It was a peaty soil mixed with sand, so charged with humus as to be quite dark colored. Some grew on the hummocks made by the matted roots of the osmunda, the roots of the two ferns being interlaced, but they were more frequently seen in bare spaces between the hummocks, which in the early spring or rainy season must have been quite wet, or even have had water resting on them for a time. Some were growing in soil principally made of the much decayed remnants of a fallen tree. In all conditions it was a soil of a strongly humus composition. This was a surprise to me, for in all previous collections or examinations of this fern the soil had been clay, often a rather stiff clay-loam, or sand as in the dune region east of Chicago. Finding the tupelo led me to search for another plant which I have quite generally found associated with it, *Bartonia tenella*. It was soon discovered on the little hummocks made by ferns, mosses, and other plants, or on abandoned ant hills beneath the trees. The association seems more than casual but may only be due to soil conditions.

The immediate shores of White lake differed considerably in the character of the flora on opposite sides. On the north side was a flat strip of sandy ground, slightly above the level of the water and lying between it and the bluffy shore. It was low enough to be subject to wave action when the winds were strong, or to freshets when the water of the river was high. Here shrubs were scarcely seen, the plants being those of wet sand and shallow pools. *Lobelia Kalmii* was very common. Other representative plants were *Gerardia purpurea*, *G. paupercula*, *Spiranthes cernua*, *Parnassia Caroliniana*, *Juncus Balticus*, *J. Richardsonianus*, and *Carex viridula*. In the shallow pools *Proserpinaca palustris* and *Potamogeton heterophyllus* occurred, the last becoming terrestrial by the drying away of the water. There were similar strips on the south shore, but between the immediate shore and the bluff there were often areas of swampy or boggy land overgrown with willow, alder, and white cedar, dense thickets which showed the influence of the adjacent springs, or of water seeping out from the banks above the clay.

The active dunes had the scanty flora so characteristic of those about Lake Michigan. The plants observed at White lake were mainly *Calamagrostis longifolia*, *Cakile Americana*, *Euphorbia polygonifolia*, *Corispermum hyssopifolium*, *Carduus Pitcheri*, *Solidago Virgaurea* var. *Gilmani*, *Salix adenophylla*, *S. glaucophylla*, *Cornus Baileyi*, *C. stolonifera*, and *Prunus pumila*. As the advance of the dune was very slow the shrubs and perennial plants were not infrequent on the windward side among the annuals much above the base of the dune, showing the ability of the seed to sprout and take root in the sand much exposed to wind action. In fact the favorite place of *Carduus Pitcheri* is everywhere on the windward side of a wind-swept area.

In the lower area of the active dune region lying between the southward bend of White lake and the shore of Lake Michigan, the two above mentioned willows were accompanied by *Salix longifolia*. Here, as frequently elsewhere along the shore, *Salix glaucophylla* had very small much thickened leaves an inch or two long by half an inch or less wide. *Hypericum Kalmianum*

was a common shrub of the locality. *Aster polyphyllus* was abundant and was also seen in higher ground south of the lake. *Cladium mariscoides* occurred in wet places, and several of the plants that have been mentioned for the low sandy borders of the north side of White lake. *Utricularia cornuta* occurred in pools. It was a small sand plain with shallow depressions and low dunes, bare or partially covered with vegetation, an area in which was to be seen a struggle with the destructive winds and a partial success in recovery.

In the deep valley of the brook which joins the old outlet of White lake some interesting forms and associations of plants were found. The white cedar was the common tree in the springy ground. Rills fed by springs along the eastern slope were frequent. Two club-mosses, which are ordinarily seen growing in different societies, were here in company, *Lycopodium lucidulum* and *L. annotinum*. Such a locality is natural to the former, but the latter is usually a denizen of drier grounds, and was here seen in company with *Medeola Virginica*, *Trientalis*, *Clintonia*, and *Viola Labradorica*. The eastern slope was scarped out of the pine plain and was densely covered with white pine and hemlock; the western was made by the high and fixed dunes which form a narrow range between the valley and Lake Michigan, with a flora similar to that of the high dunes south of White lake. In one of the quieter places of the rills a semi-aquatic or floating form of *Marchantia polymorpha* abounded. Some rested on dead leaves and twigs lodged in the water. They were not attached by rhizoids like the ordinary terrestrial form of this liverwort and could be lifted out of the water by the handful like a Lemna or a floating Riccia. The thallus was very thin, especially near the base, the thinnest parts formed of the lower series of cells which enter into the structure of the thallus, the upper or lozenge-shaped layer with the stomates being absent or prevailing in the distal portions. At first it seemed distinct, but the occasional presence of the characteristic cups and gemmules, and the structure as a whole, showed its affinities with the ordinary form found on adjoining logs and earth from which it had spread into the water.

Duck lake is similar to White lake but much smaller. Its southern shore is considerably higher than the northern. The water is clear and quite cool, being well supplied with springs and having only a small stream entering its head. There is a narrow belt of moving sand lying between it and Lake Michigan. To the south are high dunes, skirting the Michigan shore between it and Muskrat lake. The upper end is very reedy, and there is an abundance of aquatics in its shallow parts. In White lake I had found the usual potamogetons to be *P. pectinatus*, *P. perfoliatus* var. *lanceolatus*, *P. lonchites*, *P. amplifolius*, and *P. heterophyllus*. These were also common forms in Duck lake together with *P. natans*, *P. zosteraefolius*, and *P. Robbinsii*. The last had not reached the stage of mature fruit, which is in September and October, but was well provided with flowers and young fruit. This was interesting because it showed that the species may fruit under such conditions as potamogetons ordinarily do. It is usual to find the stems barren, and they are generally said to fruit, if they fruit at all, in shallow water or when ponds in which they grow partly dry up. This was the case in the only locality where I had previously found it fruiting freely, the Chesago lakes, Minnesota. It is very abundant in some of the small lakes of northern Illinois, where the stems are mostly from one and a half to two or three feet long and very leafy. In Duck lake they were less leafy as a whole, the fruiting stems four to six feet long, as this was about the depth of the water. They were rising and bringing the inflorescence to the surface of the water, or near to it, like *P. pectinatus* and the others with which it grew. All were flourishing equally well in the dark ooze which overspread the bottom where they stood, and according to their season were equally well provided with fruit or the promise of it. Nor was there any evidence of the shallowing of the water, except the contrast between summer and the rainy season, not very marked in a lake of this character fed by springs.

The high dunes to the south of Duck lake had on their slopes frequent patches of the yew, *Taxus Canadensis*. On the north slope of one whose base is washed by the waters of the lake it

was a surprise to find *Polypodium vulgare* growing on the sand of the hillside under pines and hemlocks and closely associated with the yew. The beech stood close by. It was strange to get the polypod, the yew, and the beech-drop (*Epiphegus Virginiana*) growing in the same sandy soil and near neighbors. The fronds of the polypod were fine fruiting specimens from three to twelve inches high. It was the first time I had met with it except on rocks. *Aspidium marginale* was likewise a frequent fern on the slope of the hills. It attained a very luxuriant size in the depressions among them, where fronds three feet high were measured. This fern was also common on the east or wooded side of the dune lying between the old outlet of White lake and Lake Michigan, growing here also with the yew under the pines and hemlocks.

South of Muskrat lake is a large fine tract of primitive forest as yet but little touched by fire or the woodman's axe. It is on a sandy, gently undulating, or in places almost level, plain. It is known as the "beech woods," as these trees abound and fine examples of them occur. Being dense the undergrowth was not extensive, but like that of the denser woods lying between White and Duck lakes.

Once I met with the cancer root, *Conopholis Americana*, but the abundant parasite, so-called, in all such woods is *Epiphegus Virginiana*. It is closely associated with the common beech, but I do not succeed in making out any very definite connection between it and the roots of the beech tree. As regards the soil the bulbous or thickened base of this plant is very superficial in position. Some of them have finer roots which run deeper, but the short, simple, or branched organs which cover the surface of the bulb and give to it its rough exterior do not have a root connection. They point in almost all directions and are often found springing from the stem above the place where the scaly leaves appear. The tip of these organs is slightly enlarged, of open tissue without epidermis. There is no similarity here between this and the strong union, or large haustorium, one finds in the case of the allied broom rape, Conopholis, and its host

tree, which I have found to be the oak, or in one case a hickory, and in which the parasitism as seen in section reminds one of that of the mistletoe. There are dozens of these organs on the bulb-like base which lies among the leaves and the humus made by their decay and must be in close contact with them on every side. A saprophytic relation is forcibly suggested, and one connected with beech leaves rather than with the roots of the beech, for the association is always with the beech tree. The leaves have an acid flavor and the wood is one of the best to yield wood vinegar by destructive distillation. The fresh seedlings of the beech, also called beech drops, are pleasantly acid to the taste, and their large cotyledons are eagerly eaten by children as they come up in the spring. It is possible that there is in the beech leaves or the mold made by their decay something which suits the nature of the Epiphegus.

Quite frequent in the beech and oak woods was a mycorhizal plant, *Corallorhiza multiflora*. Its mass of toothed, coral-like roots are buried much deeper in the soil than the bulb of the Epiphegus, sometimes to the depth of two or three inches. Many fine examples of these were seen, some with paler, yellow scapes and flowers, the color reminding one of *C. innata*.

Two introduced plants found in the outskirts of Montague proved of special interest. *Gypsophila muralis* was growing in the dry sand of a little used street. It has the habit of *Arenaria patula*, but a habitat more congenial to *A. stricta* as seen about the great lakes, for I have met with the former only on the thin soil of limestone rocks, where it may be accompanied by *A. stricta*, a common plant of the dune region of northern Indiana. The other immigrant was *Sedum acre*. It formed dense patches by the side of the street and had spread into the adjoining woods, closely covering the ground like a mat, and making an excellent sand binder, green and turfy looking. It was occasionally seen in other places about White lake. As a rock plant I have found it in Illinois in company with *Arenaria patula*.

The physical conditions about White lake and similar tracts of sand-filled depressions along the eastern shore of Lake

Michigan furnish fine illustrations of the ability of plants, and especially trees, to spread from an area where the conditions of growth are more favorable to one where they may be much less so. They emphasize the plasticity of plants. The species may suffer in vigor of growth and have a much less bulk, but they usually fruit very freely, often surprisingly so. At White lake was a basin filled with sand surrounded and underlaid by drift clay, or by materials that enter into the drift formation and on which in our latitude the mixed forests of deciduous species mainly occur. North of the lake, with its deeper and drier sand, the oaks were almost the only kinds to come in and compete with the white pine. South of the lake, where there was more dampness and a nearer approach of the glacial drift to the surface, except on the high dunes, and a more marked tendency to a loamy condition of soil, there were many more kinds of trees and herbaceous plants to share the ground with the pine. But the trees best adapted to a clayey soil not only crept across the area of low sand ridges and the intervening and more favorable hollows but passed up and appeared in force on the high dunes along the Lake Michigan shore, just as they may be seen on a narrow strip of dunes superposed on the clay of the lake shore, where a hardwood forest closely abuts it without any sand-filled basin to the eastward.

I have been struck repeatedly by the distribution of some of the deciduous trees of dune regions, such as that at the head of Lake Michigan in Indiana and Illinois. The basswood is one of the best examples. It appears eastward in the area of broken or active dunes where it is practically confined to a narrow belt by the lake shore and to a similar belt further south along the Calumet river. It frequents the more protected slopes of dunes or hollows lying between neighboring sand hills, though like other trees, from the shifting character of this portion of the dune region, it may be so situated as to give the appearance of growing originally on a crest. West and south it appears again in the area of low sand ridges and shallow lakes and ponds where the conditions are more like those of forest

strips or islands of the prairie region, where it is accompanied by such trees as *Quercus bicolor*, *Q. rubra*, and *Q. acuminata*, additional to the common black oaks which are spread throughout the dune region. Other trees are the hackberry, white elm, tulip tree, shagbark and bitternut hickories, white ash, blue ash and some kinds of Crataegus. Most of these are common trees on the drift clay to the south and west, and all appear somewhere on the bordering clay-land forests, but are scarcely seen in the area of broken dunes, except an occasional red oak, some white oak and bur oak or a bushy form of the Celtis specifically distinct (*C. pumila* Pursh). Lying between these two sections is a strip where the basswood as well as these other trees is absent. There would seem to be sufficient moisture at least, for it is mostly a region of low sand dunes, parallel sand ridges, and intervening sloughs, the ridges with a prevailing heath vegetation. It is the home of the gray pine (*Pinus divaricata*), sometimes almost exclusively so. Where the white pine prevails or shares the ground more freely with the gray pine, the basswood comes in. This is a common tree of the forests to the eastward of these dunes in the drift covered areas, together with the sugar maple, beech, tulip tree, and various other kinds. But nearly all except the basswood and the oaks cease in the belt of less pure sand or sandy loam, lying between the dunes proper and the clay region. There may be in the basswood peculiarities of structure or physiological adaptations better fitting it for xerophytic conditions than the others when they move away from such as are suited to mesophytes. Its leaves become much thicker than when growing in its usual home. There is in the fruit one advantage for more effectual dispersion, the ligulate bract attached to its peduncle, which in a strong wind helps to carry it to quite a distance from the parent tree. Most of the trees which formed the mixed forest to the south of White lake, and like the basswood showed this ability to spread away from a contiguous region more congenial to them, not only fruit freely but have a heavy seed, which, when lying on the surface of the ground, is not easily displaced. Such seeds sprout quickly in

the spring when there is most moisture and when the temperature is moderate. Being well provided with food stored within their coats they can carry on the processes of vegetation till the seedling is well rooted. Thus being more independent of external conditions they have an advantage in establishing themselves in a less favorable environment, such as that of dry sand.

In considering the vegetation of dune areas, especially those of the "Michigan sands," such as appear by White lake, we must also bear in mind that some of them are comparatively well provided with alkaline earths, that all have some amount of these or there would be no tree growth at least. They often produce abundant crops of fruit, especially of kinds that do best in light soil, like the peach. The prevailing constituent of the soil is silex, but microscopic examination and chemical tests show that feldspar, mica, pyroxene, and other minerals are present, such as contain potash, soda, lime, and magnesia, the most important of the alkaline earths. The pebbles of the shingle along the beach are a mixture of various kinds, quartz prevailing, but feldspars frequent, with some limestone. This must be the case since they are mainly produced by the degradation of drift material. The comminuted sands formed from them must necessarily contain the same ingredients, though the harder, coarser, and more resistant quartz sand will be most conspicuous to the eye as well as most abundant. The percentage of ash in the wood of such trees as form the principal covering of a dune region is relatively small. As seen in the analysis reported in the volume of the Tenth Census on the forest trees of North America, the pines have an average range of .19 to .23 per cent. The two most common oaks, *Q. velutina* and *Q. coccinea*, have .28 and .19 per cent. respectively. The white oak and the bur oak are higher but are much less common trees. The leaves and bark would show a higher percentage, but as they fall and the trees decay this is not only restored to the soil but they take with them other important ingredients which enter into the composition of humus. The beech, sugar maple, basswood, hemlock, and some other forest trees likewise stand considerably

higher than the pines and the most common oaks in their percentage of ash, but they, too, are much less common, often wholly absent from large areas. In general, analyses seem to show a smaller percentage of ash in the same species when growing on sandy or gravelly soil than on soils stronger in such mineral ingredients as the trees use, like clay, clay-loam, or lime soils.

But alongside of mineral constituents certain physical conditions are equally important or indispensable. The ability to reach and appropriate what is provided must exist. Porosity, depth of soil, moisture, here come into play. The last is the most important of all in soil conditions, since vegetable life is impossible without some degree of it. For porosity sand ranks the highest, in capability of retaining water it is the lowest, clay being the highest; in capacity for condensing moisture from the air, it is likewise the least powerful, humus and clay being best. In discussing such matters as these, Schlich well states what must have become evident to any who have made a comparative study of the vegetation of the dunes and of the bordering region. Though written with reference to cultivated woods it is as true of the natural forests. "Woods thrive equally well on soils of the most different geological origin, while great differences exist in the development of the same species if grown on soils of the same geological origin. The phenomena are explained by the great importance of the physical qualities of the soil, depth, porosity, and a proper degree of moisture"[1] These conditions go far toward explaining the differences in vegetation seen on the opposite sides of White lake and in corresponding regions, for they are true of vegetation as a whole as well as of the trees. In the case of the trees it was a "mixed wood," but a "mixed wood" of much greater variety on the south side where the physical constitution of the soil as well as its chemical ingredients furnished a more suitable habitat. Though it was throughout a dune formation superposed on a clay substratum, the relations of the vegetation to the substratum were also most

[1] Manual of Forestry 1 : 143. 1889.

favorable on the side of greater mixture. For the roots together with the greater supply of moisture took with this in solution the ingredients which existed in greater abundance in the comminuted soil itself. These beneficial relations also made the forest conditions more favorable in another way, and helped to perpetuate them, as they continually added to the humus, for this was much more in evidence on the side of the greater mixture.

CHICAGO, ILL.